Building data on the web: by BuildingSMART and W3C

FRIDAY 13 JANUARY 2023 – BUILDINGSMART PORTUGAL GUEST LECTURE

Pieter Pauwels, Associate Professor

Department of the Built Environment, Information Systems in the Built Environment
Who am I?

Associate Professor TU Eindhoven (2019-...)
Assistant Professor Ghent University (2016-2019)
Postdoc Ghent University (2014-2016)
Postdoc University of Amsterdam (2012-2014)
Master & PhD in Civil Engineering – Architecture @Ghent University (2008, 2012)
Building data, building data, and then more building data

Building Information Model (BIM)
3D representation enriched with semantic information

Digital Twin (DT)
Digital counterpart for a physically existing object

Linked Building Data (LBD)
Set of interlinked web-based data about the built environment

Gemini Digital Twin: combining building data with sensor data
Presentation Outline

1. Buildings and Semantics: BIM object modelling
2. The origins of ifcOWL and Linked Building Data
3. Linked Building Data (LBD)
4. Examples
The Atlas Living Lab is our newest and most sophisticated living lab, in which 10 years of experience with living labs accumulated in a flexible infrastructure and accompanying processes to conduct ground breaking research while respecting the privacy and comfort of the residents.
Object-Oriented Modelling

An information system represents information about objects (entities) that occur in the UoD (Universe of Discourse) associated with its application domain.

• **Objects** are physical (tangible) or conceptual (intangible) things in the real world.
• Objects have **properties** (attribute and value)
• **Links** define the connections between objects
• Objects are identified by a **unique identity**
Pieter Pauwels - Building data on the web: by BuildingSMART and W3C
STEP (ISO 10303) can represent 3D objects in Computer-Aided design (CAD) and related information.

STEP has an ASCII structure - a character encoding standard for electronic communication.

ICF-SPF (STEP Physical File Format)
Text format defined by ISO 10303-21 ("STEP-File"), where each line consists of a single object record.

Extensible Markup Language (XML)
is a markup language designed to store and transport data.

Resource Description Framework (RDF) is a standard model for data interchange on the Web.

**UML Class Diagram**

- DATA
  - IFC-SPF
  - XML
  - RDF

- SCHEMA
  - EXPRESS
  - XSD
  - ifcOWL

EXpress is a data definition standard developed to enable a formal definition of industrial data.

XSD (XML Schema Definition) specifies how to formally describe the elements in a XML document.

ifcOWL provides a Web Ontology Language (OWL) representation of the IFC schema.

**UML Object Diagram**
BIM data: Revit, modelling guidelines, agreements, 3D modelling, and IFC
Making building data available for a machine
BIM combined with full collaboration and coordination
Industry Foundation Classes (IFC) by buildingSMART represents an open specification for Building Information Modeling (BIM) data that is exchanged and shared among the various participants in a building construction or facility management project. The specification consists of the data schema, represented as an EXPRESS schema specification (ISO 10303-11), and reference data represented as Step files (ISO 10303-21) or XML files.
Partial Views and File Exchange

SCHEMA

MVD 1 - model.ifc

MVD 2 - model.ifc

ICDD

file.pdf
model.dgn
mep.rvt
detail.rvt
detail.dwg
word.docx
...

Inspired from T. Liebich live drafting - 2018
Data in the Industry Foundation Classes (IFC)

- Overall building shape and topology easy
- Classification of elements possible, but not many classes => extension with bSDD classes and properties possible
- Difficult (not impossible) to include sensor data (timeseries data)
- Availability in STEP, XML, RDF, and JSON

Diagram of IFC classes and relationships.
Presentation Outline

1. Buildings and Semantics: BIM object modelling
2. The origins of ifcOWL and Linked Building Data
3. Linked Building Data (LBD)
4. Examples
The WWW is a Web of Documents

- People can parse the web of documents and extract information from them to come to insights.
- We need to help machines to understand the web, so machines can help us understand things.
- If machines have access to the data about things, they can do a better job while processing documents.
The Semantic Web is needed: a Web of Data

• “The Semantic Web is an extension of the current web in which information is given well-defined meaning, better enabling computers and people to work in cooperation.” [Tim Berners-Lee et al. 2001.]

• Specific goals:
  • Build a description language with standard semantics
  • Make semantics machine-processable and understandable
  • Incorporate logical infrastructure to reason about resources
  • W3C proposals: Resource Description Framework (RDF) and SPARQL
5 ★ OPEN DATA

Tim Berners-Lee, the inventor of the Web and Linked Data initiator, suggested a 5-star deployment scheme for Open Data. Here, we give examples for each step of the stars and explain costs and benefits that come along with it.
Official Community Groups

- linkedbuildingdata.net
- www.w3.org/community/lbd/
- LDAC event

LBD

ifcOWL

LDWG

linkedbuildingdata community

[Image of community members]
Semantic web technologies (RDF & OWL) promise to enable linking building data across various sources

⇒ improved information exchange with sources outside the traditional BIM environments, additional to the already existing techniques
Example project: Infra bridge
XSD Specification

```xml
<x:simpleType name="IfcPropertySetTemplateTypeEnum">
  <x:restriction base="xs:string">
    <x:enumeration value="pset_typedefinestatic"/>
    <x:enumeration value="pset_typedefinestaticoverride"/>
    <x:enumeration value="pset_performancebased"/>
    <x:enumeration value="pset_typedefinestatic"/>
    <x:enumeration value="pset_occurrencedriven"/>
    <x:enumeration value="pset_typedefinestaticoverride"/>
    <x:enumeration value="pset_occurrencedriven"/>
    <x:enumeration value="notdefined"/>
  </x:restriction>
</x:simpleType>
```

EXPRESS Specification

OWL Specification

```owl
ifc:IfcPropertySetTemplateTypeEnum
  rdf:type owl:Class;
  owl:equivalentClass
    [ rdf:type owl:Class;
      owl:oneOf
        [ ifc:PSET_TYPedefinestatic
          ifc:PSET_TYPedefinestaticoverride
        ]
    ];
```

Demands from practice and research

1. Modularisation
2. Extensibility
3. Simplified Access
W3C LBD Community Group

Official community webpage:
https://www.w3.org/community/lbd/

Working documents webpage:
https://w3c-lbd-cg.github.io/lbd/

GitHub repository:
https://github.com/w3c-lbd-cg/

=> Minutes! Register!

=> Google Docs!

=> Ontologies! Examples!
Web of Linked Data
Combining dedicated data sets that are stored in a diversity of servers

- Granular schemas / ontologies
- Combine as preferred on instance level or schema level
- Specialized datasets
- Query access
- Availability of inference engines
A number of key ontologies at W3C LBD

- Building Topology Ontology (BOT)
- Product Ontology (PRODUCT)
- Geometry Ontology (GEOM)
- Properties Ontology (PROPS)

Industry Foundation Classes (ifcOWL)
IFC Technical Roadmap – move to the web

Bespoke, high threshold

Generic, scalable, higher adoption

https://www.buildingsmart.org/about/technical-roadmap/
Data Sharing and Live Data Access
Modular data in dedicated repositories with live query access

- Link and combine as needed
- Live data availability
Aims and objectives

1. Move away from files and instead rely on live data in live data stored that are accessible over the web

2. Avoid manual operations by all means (only good for tests)

3. Rely on a community of users and servers, as well as a network effect

4. Leave the data with the person that owns it, leave it at the real source

5. Enable web-based computation; avoid local calculations
LDAC2019
7th Linked Data in Architecture and Construction Workshop
17 - 21 June 2019
Incl. SUMMER SCHOOL!!

https://linkedbuildingdata.net/ldac2019/
Presentation Outline

1. Buildings and Semantics: BIM object modelling
2. The origins of ifcOWL and Linked Building Data
3. Linked Building Data (LBD)
4. Examples
Web of Linked Data
Combining dedicated data sets that are stored in a diversity of servers

- Granular schemas / ontologies
- Combine as preferred on instance level or schema level
- Specialized datasets
- Query access
- Availability of inference engines

Image from: Petrova et al., 2019
Building Topology Ontology (BOT)
Taxonomies of products
## Reference ontologies

<table>
<thead>
<tr>
<th>Acronym</th>
<th>URL</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOT</td>
<td><a href="https://w3id.org/bot#">https://w3id.org/bot#</a></td>
</tr>
<tr>
<td>BEO</td>
<td><a href="https://pi.pauwel.be/voc/buildingelement/">https://pi.pauwel.be/voc/buildingelement/</a></td>
</tr>
<tr>
<td>MEP</td>
<td><a href="https://pi.pauwel.be/voc/distributionelement/">https://pi.pauwel.be/voc/distributionelement/</a></td>
</tr>
<tr>
<td>OMG</td>
<td><a href="https://w3id.org/omg#">https://w3id.org/omg#</a></td>
</tr>
<tr>
<td>FOG</td>
<td><a href="https://w3id.org/fog#">https://w3id.org/fog#</a></td>
</tr>
<tr>
<td>BPO</td>
<td><a href="https://www.w3id.org/bpo#">https://www.w3id.org/bpo#</a></td>
</tr>
<tr>
<td>OPM</td>
<td><a href="https://www.w3id.org/opm#">https://www.w3id.org/opm#</a></td>
</tr>
</tbody>
</table>

Revit to LBD exporter: on demand  
IFC to LBD converter: on demand
Modular approach to building data

Pieter Pauwels - Building data on the web: by BuildingSMART and W3C
Modular ontology modelling advocated by LBD group

- Implemented using Semantic Web Technologies -> Web-scale, queryable
- Reuse of existing ontologies -> Modular
- Linking at instance level -> Multi-model method

Sample dataset available at: https://github.com/TechnicalBuildingSystems/OpenSmartHomeData
In short

Nothing that cannot be included in a modular linked building data (LBD) cloud.
Presentation Outline

1. Buildings and Semantics: BIM object modelling
2. The origins of ifcOWL and Linked Building Data
3. Linked Building Data (LBD)
4. Examples
SAREF, SOSA and SSN

Example:

```cayc
@prefix cdt: <http://w3id.org/lindt/custom_datatypes#> .
BASE <http://example.org/>
<observation/235715> a sosa:Observation ;
    sosa:hasFeatureOfInterest <house/134/kitchen> ;
    sosa:observedProperty <electricConsumption> ;
    sosa:madeBySensor <sensor/927> ;
    sosa:hasSimpleResult "22.4 kWh"^^cdt:ucum .
```

Ontology Core:

Haystack example graph
Semantic graph of sensors

@prefix brick: <https://brickschema.org/schema/Brick#> .
@prefix inst: <http://linkedbuildingdata.net/ifc/resources20201208_005325/> .
@prefix ph: <https://project-haystack.org/def/ph/3.9.11#> .
@prefix phIoT: <https://project-haystack.org/def/phIoT/3.9.11#> .
@prefix phScience: <https://project-haystack.org/def/phScience/3.9.11#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .

inst:11NR008LT-001PIRTM a brick:Occupancy_Sensor,
  phIoT:sensor ;
  rdfs:label "PRESENCE_8_128"^^xsd:string ;
  brick:hasLocation inst:space_892 ;
  ph:dis "PRESENCE_8_128"^^xsd:string ;
  ph:hasTag phIoT:his,
    phIoT:occupancy ;
  phIoT:spaceRef inst:space_892 .

inst:11NR008LT-003PIRTM a brick:Occupancy_Sensor,
  phIoT:sensor ;
  rdfs:label "PRESENCE_8_127"^^xsd:string ;
  brick:hasLocation inst:space_1023 ;
  ph:dis "PRESENCE_8_127"^^xsd:string ;
  ph:hasTag phIoT:his,
    phIoT:occupancy ;
  phIoT:spaceRef inst:space_1023 .

See presentation Lasitha Chamari on Wednesday 25 May.
Pieter Pauwels - Building data on the web: by BuildingSMART and W3C
A building has different types of data associated

https://www.youtube.com/watch?v=b7LKU3C6gCQ
Thank you

Questions?

Pieter Pauwels - P.Pauwels@tue.nl